A CLASSIFICATION OF WEATHER TYPES[1]

By E. S. NICHOLS

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Consideration of monthly and annual means, totals and extremes of the various meteorological elements is merely the beginning in the study of the climate of a place. As instances of progress toward more detailed analysis of our records we have Professor Marvin's proposal to use the week as a time unit for the grouping of data; we have studies of hourly precipitation data; and we have an increasing number of investigations of the frequencies of the different meteorological elements.

THE NEED OF STUDYING COMBINATIONS OF ELEMENTS

Dr. C. F. Brooks has pointed out[2] that in studying the average conditions, "* * * we have some idea of the climate, but we have not got a correct picture. How are these elements interrelated in their modes of occurrence? Are the cold days always dry? If not, what proportion are wet? The effects of the cold are much more severe on cloudy, wet, windy days than on clear quiet ones. With a given set of temperatures, and one of winds, for example, the climate would be a much severer one if all the cold days were windy and all the warm days quiet, than if all the cold days were quiet and all the warm ones windy. Yet the data as presented would not show this."

He then suggests that 10 or 20 classes of weather be specified in terms of degrees or intensities of sunshine, temperature, rainfall or humidity (relative or absolute), and wind velocity. No two classes should overlap, yet the classes should include all conditions that can occur. E. g., one class might be: "Sunny—Hot—Humid—and—Windy," in which sunny meant less than half the sky covered with clouds; hot, a temperature above a certain figure; humid, a humidity above a certain value; and windy, a wind velocity above a certain speed. Now if there are only two classes of each of these four elements, 16 combinations are possible; and if three classes of temperature are specified there will be 24 classes by the various combinations, with two each of the other three.

More attention given to the combinations of climatological elements, as Doctor Brooks suggests, will undoubtedly produce valuable results. We may consider in the same way not only daily weather, but combinations for other periods as well; thus, we may study the frequencies of months having certain characteristics according to the scale—how many Julys are hot-humid-sunny-windy, how many are cool-dry-sunny-quiet, etc.

In the papers of this group by Howe and Switzer, data for humidity and sunshine are necessarily replaced by those for precipitation, which can, of course, very inadequately fulfill the requirements. For at least two other reasons, moreover, we must go still further if we are to get the most out of a study of weather types:

First, the scales suggested by the above-named writers are of necessity so coarse as to obscure important variations, particularly if they be intended to apply to all climates. Therefore, I have designed a much finer scale of weather types, having 10 temperature divisions, six of relative humidity, 4 of wind, and 3 of sunshine (or cloudiness). This scale provides for 720 different types of weather.

Second, we do not experience the daily mean temperature, the average wind velocity, etc. Nor is the weather that actually occurs constant for a month or even for a day. It is a composite of several variables, particularly of the four elements we employ, and an exact and complete picture can be obtained only by examining these composites as they exist at certain instants of time. It is not sufficient even to take the averages of conditions that occur at certain times of the day. Thus, at St. Louis, Mo., at the regular morning observation, begun at about 6:40 a. m., during January, 1907, the average cloudiness was 6.6 (according to the scale, 0 to 10,) which is partly cloudy according to the usual classification. However, at only 4 of the 31 observations considered was the sky actually partly cloudy. We should, therefore, examine the *frequencies of the various types of weather that occur*. At first thought it may appear that we have undertaken a hopelessly complicated task; but experience shows that it is possible easily and quickly to analyze weather observations in this way, largely because the number of types that occur at a place during a month or other period likely to be examined is comparatively few.

PROPOSED SCALE FOR CLASSIFICATION OF WEATHER TYPES

Each division of the scale under temperature, relative humidity, wind velocity, and sunshine and cloudiness has definite limits; hence classification depends upon the records, not on personal impressions. Each class is designated by an appropriate letter with subscript; and is further defined by an adjective interpreting it according to the writer's experience. Each of the 720 possible types may be conveniently designated by a combination of four adjectives, or of four letters with subscripts, as may be preferred. Thus, $T_oH_{+1}W_oS_2$ indicates "Moderate temperature, humid, quiet, sunny;" or, more definitely, temperature from 60° to 74° F., relative humidity from 75 to 84 per cent, wind velocity less than 10 miles per hour, and clear sky.

TABLE 1. *Scale for classification of weather types*

TEMPERATURE (°F. AND °C.)		
T_{+4}	Scorching	106° (41° C.) and higher.
T_{+3}	Very hot	96° to 105° (35.5° to 40.5° C.).
T_{+2}	Hot	85° to 95° (29.5 to 35.0° C.).
T_{+1}	Warm	75° to 84° (24.0° to 29.0° C.).
T_o	Moderate	60° to 74° (15.5° to 23.5° C.).
T_{-1}	Cool	40° to 59° (4.5° to 15.0° C.).
T_{-2}	Cold	20° to 39° (−6.5° to 4.0° C.).
T_{-3}	Very cold	0° to 19° (−18° to −7° C.).
T_{-4}	Frigid	−20° to −1° (−29° to −18.5° C.).
T_{-5}	Polar	Below −20° (below −29° C.).
RELATIVE HUMIDITY (PERCENTAGES)		
H_{+2}	Damp	85 and above.
H_{+1}	Humid	75 to 84.
H_o	Moderate	50 to 74.
H_{-1}	Dry	30 to 49.
H_{-2}	Very dry	15 to 29.
H_{-3}	Excessively dry	Below 15.
WIND VELOCITY (M. P. H. AND M. P. S.)		
W_3	Storm winds	35 m. p. h. (15.6 m. p. s.) and above.
W_2	Strong	20 to 34 (8.9 to 15.2 m. p. s.).
W_1	Moderate	10 to 19 (4.5 to 8.5 m. p. s.).
W_o	Light	0 to 9 (0 to 4 m. p. s.).
SUNSHINE AND CLOUDINESS		
S_2	Clear	0–3 tenths of sky cloud-covered.
S_1	Partly cloudy	4–7 tenths of sky cloud-covered.
S_o	Cloudy	8–10 tenths of sky cloud-covered.

[1] Presented before the American Meteorological Society at Stanford University, June 26, 1924.

[2] In course on Climatology and Climates of the World, Home Study Department, Clark University.

TABLE 2.—*Frequencies of selected weather types, San Jose, Calif.*

			H_{-2}			H_{-1}			H_0			H_{1+}			H_{+2}		
			W_0	W_1	W_2	W_0	W_1	W_2	W_0	W_1	W_2	W_0	W_1	W_2	W_0	W_1	W_2
6.40 a. m. observations January, 1923	T_{+1}	S_2													1		
		S_1													1		
		S_0										1	3		8	1	
	T_{-1}	S_2													7		
		S_1													3		
		S_0													6		
Noon observations January, 1923	T_0	S_2							1								
		S_1															
		S_0															
	T_{-1}	S_2				1	1		5	1							
		S_1							4							1	
		S_0							5			9			3		
January, 1923, 4.40 p. m. observations	T_{-1}	S_2				1			9	2							
		S_1								1		3					
		S_0							4	1		7	1		1	1	
April, 1923, 6.40 a. m. observations	T_{-1}	S_2										5			5		
		S_1							1						3		
		S_0							2			5			7	2	
April, 1923, noon observations	T_{+1}	S_2				2											
		S_1															
		S_0															
	T_0	S_2	1	1		5	1			2							
		S_1							1	2							
		S_0				1			4	2							
	T_{-1}	S_2								1							
		S_1															
		S_0				1	1		1	1		1		1	1		
April, 1923, 4.40 p. m. observations	T_{+1}	S_2		1													
		S_1															
		S_0															
	T_0	S_2		1			4			7							
		S_1				1	1										
		S_0				1			1	3							
	T_{-1}	S_2								1	1						
		S_1							1				1		1		1
		S_0							1	3							
July, 1923, 6.10 a. m. observations	T_0	S_2										8	1		6		
		S_1										1	1		2		
		S_0							1			3			6		
	T_{-1}	S_2															
		S_1										1					
		S_0							1								
July, 1923, noon observations	T_{+2}	S_2				1											
		S_1	1														
		S_0															
	T_{+1}	S_2				7	7		2	1							
		S_1							1								
		S_0															
	T_0	S_2					1		5	4							
		S_1				1											
		S_0															
July 1923, 4:40 p. m.	T_{+2}	S_2				1	2										
		S_1															
		S_0															
	T_{+1}	S_2					5			4							
		S_1															
		S_0															
	T_0	S_2					5		1	12							
		S_1								1							
		S_0															
October, 1921, 6:40 a. m.	T_0	S_2															
		S_1													2		
		S_0													5		
	T_{-1}	S_2										3			2		
		S_1													15	1	
		S_0										2			1		
	T_{-2}	S_2															
		S_1															
		S_0															
October, 1921, noon	T_{+1}	S_2	3			2			1			1					
		S_1							1								
		S_0															
	T_0	S_2				3			7	1		1					
		S_1				1			2	1							
		S_0							5								
	T_{-1}	S_2															
		S_1							1								
		S_0							1								
October, 1921, 4:40 p. m.	T_{+2}	S_2				1											
		S_1															
		S_0															
	T_{+1}	S_2				2	1										
		S_1				1											
		S_0															
	T_0	S_2				3	1		5	4		1	1				
		S_1					1		2	1							
		S_0							3						1		
	T_{-1}	S_2							1	1							
		S_1															
		S_0										1					
10 very hot days at time of max. temp.: June and July, 1921. June, 1922. July and Sept., 1923.	T_{+3}	S_2	3	7													
		S_1															
		S_0															

In illustration of the use of the scale, in Tables 2 and 3 we have a group of lines for each temperature class and a group of columns for each relative-humidity class. Under each temperature head is a line for each sunshine division; and under each humidity head is a column for each wind-velocity class. In this way we provide a separate space for each of the 720 weather types, or for as many thereof as may be necessary. Suppose we have observed temperature 85°, rel. hum. 35 per cent, wind vel. 8 m. p. h., and clear sky; 85° determines the T_{+2} temperature belt and 35 per cent confines us to the H_{-1} humidity group; and the two conditions place us somewhere in the few types common to belt and group; 8 m. p. h. selects the left-hand column of types and clear sky the upper space, in which we enter a tally mark. Thus we can quickly classify a large number of observations.

In the arrangement used in this case we have emphasized temperature and humidity classes; for all cases in any temperature class appear in a belt extending across the table; and all in a given humidity class appear in a certain group of columns. However, all cases of clear skies occur in the upper lines of the several belts, all cloudy cases in the lowest, and partly cloudy cases in the middle lines. Similarly, classes of light winds are in left-hand columns of groups, while stronger wind cases are placed farther and farther to the right as strength increases. While the prominence of wind and sunshine classes can be made out with little trouble, these divisions could be made more prominent by arranging belts or groups according to wind and sunshine headings. Also, if for any reason we wish to investigate combinations of only two or three meteorological elements, we may omit the unnecessary division or divisions. For instance, temperature and humidity require only a simple set of lines and columns, as we have in Figure 2. Again, we might substitute pressure or some other weather element for any of those we have chosen.

APPLICATION OF THE SCALE TO WEATHER RECORDS

This system is herein first applied to the records of the Weather Bureau office in San Jose, Calif., for the four months, January, April, and July, 1923, and October, 1921. We may gain an excellent idea of the weather throughout the day by studying the conditions that prevail during the warmest hours, the coldest hours, and transition hours. A close approximation to this is provided by the regular thrice-daily observations begun at about 6:40 a. m. (6:10 a. m., from June 1, 1923), local mean noon, and 4:40 p. m. Therefore, in Table 2 have been entered the frequency numbers of the different types of weather observed during the four months considered, each set of observations tabulated separately for each month, making 12 sections in the table, or, rather, 12 separate tables.

For an extended climatic study one should determine percentages of frequencies of various types for each month or other desired periods over a term of years. The months chosen are, however, fairly typical of San Jose's climate, and serve to exemplify the method.

Beginning with January mornings, we note that nearly all the 31 cases fall in the "damp" class; over one-half are "cool," and the remainder are "cold"; nearly all have light winds; about one-half are cloudy; about one-half fall in the two types, "humid-cloudy-light wind-and-cool or cold." "Damp" characterizes nearly all October mornings also, especially numerous being the cool-light wind-cloudy type. April has many of the same types, or of those with the next lower humidity class. July mornings are similar to those of April, but with next higher temperature class, "moderate."

The similar types $T_{-2}H_{+2}W_0S_0$ and $T_{-1}H_{+2}W_0S_0$ are gloomy and might be depressing to some temperaments, especially when foggy or rainy as well; when in the lower temperature class they are chilly, in the other cooling; but the absence of even moderate winds makes them not at all disagreeable. In fact the quiet, damp or humid, cloudy or partly cloudy, cool or cold mornings so numerous at all times of the year are sedative, particularly to a person that has recently come from a very dry, hot, windy climate. The type $T_{-2}H_{+2}W_0S_2$, numerous in morning in January, is frosty weather.

At noon and at night in January the cold types disappear, and cool are almost universal. The very frequent afternoon type $T_{-1}H_0W_0S_2$ is invigorating.

Higher wind and sunshine classes, with lower humidity are more frequent at noon and in afternoon than in morning at all seasons. Particularly worthy of mention is the class $T_0H_0W_1S_2$, which is noted at nearly one-half the late afternoon observations in July, at nearly one-fourth of those observations in April, and at some in October. Outdoor life in this type is agreeable, particularly if physical exertion be moderate only. The types with "moderate" or "dry" as regards humidity and "cool" for temperature favor vigorous physical exertion, whether cloudy or sunny, quiet or moderately windy; these are numerous during the day in January and occur in spring and fall also, rarely in midsummer. Mental activity is favored by cool or moderate temperature accompanied by moderate humidity or humid air, particularly if wind be light and the sky sunny; these types are most typical of San Jose's climate as a whole, including winter days (see January afternoons).

Cases under "dry" are most numerous with moderate or warm temperatures and sunny skies, while the wind is moderate many times, particularly in July. With four exceptions at noon and four in the afternoon in July and two at noon in October, all "warm" or "hot" observations were in "dry" or "very dry" classes. This decrease of relative humidity with temperature increase maintains, to a great extent, the agreeable features of moderate temperatures; because of the increased cooling resulting from more rapid evaporation of perspiration from the skin. This cooling is further increased by increase of wind velocity, as noted above for July. The large classes $T_{+1}H_{-1}$ and $T_{+1}H_0$ are somewhat too warm for the best physical and mental activity; they are most enjoyed sitting in the shade, which is still more emphatically true of cases in "hot" classes, which are infrequent.

Only a few cases fall in the "Very dry" columns. Almost all of these occurred in April and October with sunny skies and moderate or warm temperatures. The only other case falls at noon in July on a "hot" day. Although the cooling effect, on a perspiring skin, is great when the air is very dry, the extreme dryness, especially if long continued and accompanied by strong winds and high temperatures, is injurious. The skin becomes dry and rough; lips crack; a phlegmatic person is stimulated; nervous people become restive and afflicted with insomina. San Jose is, therefore, fortunate in having few cases in these types. During the period examined there were none in "excessively dry" classes, which still more effectively produce the results mentioned above. Such cases do occur at wide intervals.

No case occurred in temperature classes above "hot," among the observations examined. As an additional matter of interest the conditions on 10 "very hot" days, occurring at intervals during the past three years, at times of the maximum temperatures were examined, and will be found at the bottom of Table 2. Relative humidity was determined by interpolating for the dew-point between the noon and evening observations, between which the maximum temperatures always occurred, obtaining the probable depression of the wet-bulb thermometer from dew-point table, and then the relative humidity by the usual method. All 10 cases fell within the two types $T_{+3}H_{-2}S_2$ and W_0 or W_1, 3 and 7, respectively, and illustrate the usual conditions at San Jose during very hot spells. Being short and infrequent and neither excessively dry nor very windy, these spells produce little or no permanent bad effect, although they are uncomfortable during the hottest hours of the day.

TABLE 3.—*Form of table for showing frequencies of 720 selected weather types. Entries in the table are for the means of 4:40 p. m. observations for July during the 3 years 1905–1907, comparing Fresno, Calif., (italic figures) with San Francisco (bold-face figures)*

Temperature	Sunshine	Relative humidity and winds [1]																							
		H_{-3} (Below 15 per cent) excessively dry				H_{-2} (15 to 20 per cent) very dry				H_{-1} (30 to 49 per cent) dry				H_0 (50 to 74 per cent) moderate				H_{+1} (75 to 84 per cent) humid				H_{+2} (85 to 100 per cent) damp			
		W_0	W_1	W_2	W_3	W_0	W_1	W_2	W_3	W_0	W_1	W_2	W_3	W_0	W_1	W_2	W_3	W_0	W_1	W_2	W_3	W_0	W_1	W_2	W_3
T_{+4} (106° and above) scorching	S_2 Clear	*3*	*7*			*2*	*1*																		
	S_1 Partly cloudy																								
	S_0 Cloudy																								
T_{+3} (96° to 105°) very hot	S_2 Clear	*52*	*12*			*7*	*2*																		
	S_1 Partly cloudy																								
	S_0 Cloudy																								
T_{+2} (85° to 95°) hot	S_2 Clear	*8*	*5*			*8*	*3*	*1*																	
	S_1 Partly cloudy					*1*	*1*																		
	S_0 Cloudy		*1*																						
T_{+1} (75° to 84°) warm	S_2 Clear											*1*													
	S_1 Partly cloudy																								
	S_0 Cloudy																								
T_0 (60° to 74°) moderate	S_2 Clear										*1*	*2*		*2*	*9*	*7*			*6*						
	S_1 Partly cloudy														*1*				*2*						
	S_0 Cloudy																	*1*	*3*				*1*		
T_{-1} (40° to 59°) cool	S_2 Clear														*2*	*1*			*7*	*5*	*1*		*2*	*1*	
	S_1 Partly cloudy																		*3*	*4*				*4*	
	S_0 Cloudy																	*1*	*6*	*2*		*1*	*13*	*3*	
T_{-2} (20° to 39°) cold	S_2 Clear																								
	S_1 Partly cloudy																								
	S_0 Cloudy																								
T_{-3} (0° to 19°) very cold	S_2 Clear																								
	S_1 Partly cloudy																								
	S_0 Cloudy																								
T_{-4} (−20° to −1°) frigid	S_2 Clear																								
	S_1 Partly cloudy																								
	S_0 Cloudy																								
T_{-5} (−21° and below) polar	S_2 Clear																								
	S_1 Partly cloudy																								
	S_0 Cloudy																								

[1] W_0=Light (0-9); W_1=moderate (10-19); W_2=strong (20-34); W_3=stormy (35 and over).

Thus we might continue our inquiry into the climate of San Jose. Gathering the facts from any one section of a table such as I have prepared for that city is very easy.

COMPARISON OF CLIMATES

As suggested above, the recording of weather types for any one station will usually require the use of but a part of the whole range of types in the complete classification Obviously the greater the range of climatic conditions at a given station the larger will be the section of the classification needed.

When we wish to *compare* stations (entries in the table being made with various types and colors of figures corresponding to the stations and months or seasons) it may or may not be necessary to prepare the complete form of table for 720 types. It would be necessary, for instance, in comparing certain low-latitude desert stations with certain high-latitude interior continental stations. It would not be necessary in comparing stations having very similar climates. For instance, if we compare conditions at St. Paul, Minn., at 6:40 a. m. during January, 1907, with those that prevailed at St. Louis, Mo., at the same time, we need five temperature groups (T_0 to T_{-4}, inclusive) and three relative humidity groups (H_0 to H_{+2}, inclusive) only. If, however, we compare afternoon conditions during July at San Francisco, Calif., with those existing at Fresno in the same State at the same time, we require a much larger section of the table; in fact all the humidity classes and the six upper temperature groups are necessary, as is shown in Table III, where I have made such comparison, using data for the three-year period, 1905–1907.

Various possibilities of applying graphic methods to the depicting of weather types based on the classification here proposed, will occur to the reader, though space does not permit of their discussion here.

CONCLUSION

The writer believes that, from a set of weather-type frequency numbers such as those presented here for San Jose (at least if frequency percentages be derived from records for several years) the degree of suitability of a climate for health, pleasure, certain industrial and agricultural operations and many other purposes, can be ascertained to greater advantage than by any other known method; and, further, that some such analysis of the original observations is necessary to an adequate conception of a climate.

WEATHER TYPES IN THE CLIMATES OF MEXICO, THE CANAL ZONE, AND CUBA[1]

By J. ELMER SWITZER, Ph. D.

[Indiana University, Bloomington, Ind., December, 1923]

This study of the frequency of weather types in the climate of certain cities in Mexico, the Canal Zone, and Cuba is an effort to determine the actual weather experienced by the inhabitants of these stations within the Tropics.

As a more systematic attempt is made to develop this part of the world, the problem of adjustment by white man to the conditions of tropical climate will become more and more important. The frequency of unfavorable types of weather at given stations and the frequency of interruptions in the sequence by a more favorable type will become significant in a greater degree, since the development of the vast resources of the Tropics depends upon the ability of progressive peoples to live and work in the climatic conditions found there. Thus it seems that a study of the weather conditions to be encountered from day to day is appropriate.

An effort is made to group the different elements together into the weather types which seem to affect man most and to determine the frequency of each in the climate of the nine stations for which the necessary data were available, and to determine also in some degree the sequences of the various types. The stations are located as follows: Colon and Balboa Heights at the Atlantic and Pacific termini, respectively, of the Canal Zone; Vera Cruz, Progreso, and Matamoros, on the east coast of Mexico; Salina Cruz and Manzanillo, on the west coast; Mexico City, on the plateau; and Habana, Cuba. They range in latitude from about 9° N. to about 26° N. All are near sea-level except Mexico City, which has an elevation of about 7,000 feet above mean sea level.[2]

Certain arbitrary classifications of weather types are made. All days with mean temperatures (generally taken as (max.+min.)/2) over 68° F. are classed as "hot," those with mean temperatures between 50° F. and 68° F. are considered "moderate," while those with mean temperatures between 32° F. and 50° F. are designated as "cool." If the wind during the day reached a maximum velocity of 25 miles per hour for a five-minute period or longer, the day is considered "windy." Days with 0.01 inch or more of rain are called rainy days. By combining these factors, the following nine weather types are adopted: Hot-rainy, hot-fair-and-windy, hot-fair-and-quiet, moderate-rainy, moderate-fair-and-windy, moderate-fair-and-quiet, cool-rainy, cool-fair-and-windy, cool-fair-and-quiet. Three additional types would be used where the mean temperature of the day was below 32° F.; i. e., cold-snowy, cold-fair-and-windy, cold-fair-and-quiet. In the stations considered in this paper the last three types were not feund.

It is recognized at the outset that this classification does not include many items it would be desirable to include, but with the present practices of compiling and recording data, even the above designated information is difficult to obtain.

The weather type each day during the five-year period 1917–1921, inclusive, was determined and charted for each of the nine stations[3] in the following way: The temperature of the day was indicated by color; red representing hot days; green, moderate days, and blue, cool days. A windy day was indicated by a square, and a quiet day by a circle. A rainy day was indicated by shading the circle or square, and an open circle or square stood for a fair day. The averages of each type were obtained by counting the whole number of times a type occurred each month for the five-year period and computing the average number of recurrences per year for that month. These were plotted on the accompanying chart as nearly as possible in proportion to their frequency of occurrence, as computed by 10-day periods.

[1] Presented before Association of American Geographers and American Meteorological Society, Cincinnati, Ohio, Dec. 27, 1923. See Bull. Am. Metl. Soc., January, 1924, vol. 5, pp. 9–11.

[2] Grateful acknowledgment is due, for their aid in the pursuit of this study, to the following people: To Maj. Z. Kirkpatrick, chief hydrographer of the Canal Zone; Sr. J. C. Jones, director Meteorologico Central, Tacubaya, Mexico; Sr. José Millás, director Observatorio Nacional, Cuba; and to Mr. P. C. Day, meteorologist in charge, Climatological Division, U. S. Weather Bureau, for the detailed data furnished; Dr. O. L. Fassig, meteorologist of Porto Rico; and J. F. Brennan, of Jamaica, for further data furnished but not incorporated in this paper; Dr. Charles F. Brooks for his helpful suggestions in securing and compiling the data.

[3] The data for Manzanillo are available for only a two-and-a-half-year period, for Habana for four years. Data are lacking for the following other stations: At Vera Cruz for February, 1918; at Salina Cruz for May and June, 1920; at Balboa Heights for April and October, 1918; and for Colon in April, 1917.